NSF-tr-186
January, 1954

Physics Translated from Doklady Akademii Nauk SSSR, 92, 269-71 (1953)

Use of a Narrow-Band Amplifier in Oscillographic Investigation of the Electron Velocity Distribution Functions in an Electrical Discharge

G. M. Malyshev and V. L. Fedorov

Considerable attention has been paid recently to methods of investigation of the electron velocity distribution function in an electrical discharge through a gas. A number of experimental investigations have dealt with the problem,[1-4] most of them based on the method of probes.

As we know,[5] the determination of the distribution function by means of probes consists mainly in finding the second derivative of the probe current taken with respect to the probe potential, d^2I/dV^2. The latest method used to obtain the second derivative, d^2I/dV^2, consists in the application of a single electrical differentiation followed by a graphical differentiation. This method requires a rather involved operational procedure which makes the investigation difficult.

Earlier methods based on superimposing a variable potential on the potential of the probe[6,7] are unsatisfactory mainly because the second derivative is obtained for points only. Finding the whole curve requires a long period of time during which the conditions of the discharge may change. This may introduce large errors in the curve obtained.

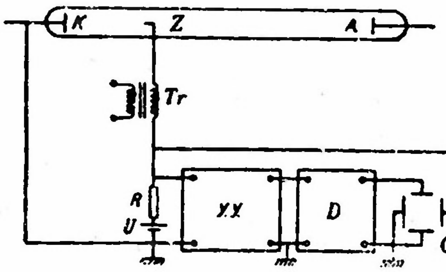

Fig. 1.

The present paper describes a method which enables us to display on the screen of an oscillograph the whole length of the curve of the second derivative of the probe current taken with respect to the probe potential.

A simplified block diagram of the setup is shown in Fig. 1. The circuit of the probe consists of the voltage source U, a complex impedance R, and a transformer Tr, connected in series. The voltage U, together with the voltage drop across the impedance R, determines the dc component of the potential of the probe Z with respect to the cathode K of the discharge tube. A variable voltage $\Delta V = V_0(1 + \cos \omega_1 t) \sin \omega_2 t$ is superimposed on the dc component of the probe potential by means of a transformer. This voltage consists of a sinusoidal voltage of frequency ω_2 modulated to the depth of 100 percent by means of frequency ω_1. Assuming impedance R to be negligibly small and expanding the resultant expression for the probe current into a series in terms of ΔV, we get, approximately

---

This translation was prepared for the National Science Foundation by the Russian Science Translation-Dictionary Project, Columbia University. It has been reproduced direct from copy as submitted to the Technical Information Service, United States Atomic Energy Commission.
Printed in USA, Price 10 Cents. Available from the Office of Technical Services, Department of Commerce, Washington 25, D. C.

$$I(V+\Delta V) = I(V) + \frac{3}{8} V_0^2 I''(V) + \ldots$$
$$\ldots \left[\frac{V_0^2}{2} I''(V) + \frac{7}{64} V_0^4 I''''(V) + \ldots\right] \cos \omega_1 t + \Sigma,$$

where Σ is the sum of component frequencies with decreasing amplitudes,

$2\omega_1,\ 3\omega_1,\ \ldots,\ \omega_2,\ 2\omega_2,\ 3\omega_2,\ \ldots,\ \omega_2 \pm \omega_1,\ \omega_2 \pm 2\omega_1,\ \omega_2 \pm 3\omega_1,\ \ldots$

The fact that the ac components of the probe current are of different frequencies permits us to separate the components of frequency ω_1. This is done by means of a narrow-band amplifier *YY* (Fig. 1) with the frequency band in the region of ω_1. As can be ascertained from the expansion, when V_0 is sufficiently small, the amplitude of the ac component of frequency ω_1 is proportional to the second derivative of the probe current taken with respect to the probe potential d^2I/dV^2.

After amplification the signal is fed into the detector *D*. A dc voltage, also proportional to d^2I/dV^2, appears as the effect of detection. This voltage is supplied to the vertical deflection plates of the cathode ray oscillograph *CO*. A voltage proportional to the dc component of the probe potential is connected to the horizontal deflection plates.

The source of voltage *U* is a special generator producing a slowly and periodically varying voltage. Since the probe potential variation is of a periodic character, the electron beam describes (during 25 sec) the whole curve of the second derivative on the screen of the oscillograph.

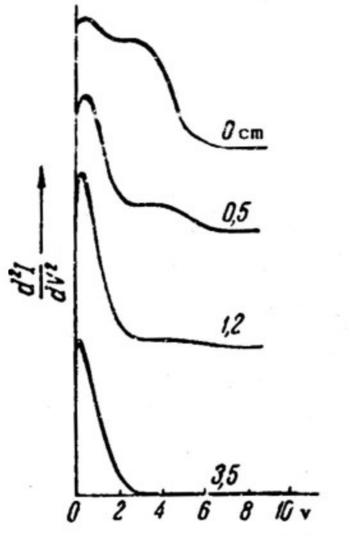

Fig. 2.

In order to determine the error, a more accurate computation may be performed with the magnitude of impedance *R* being taken into consideration. Additional terms then appear in the expansion. The error determined from them did not exceed 10 percent in our measurements.

In our investigation we used a hot, oxide-coated cathode in a discharge tube 37 mm in diameter, filled with mercury vapor.

The experiments showed that in such a discharge at a pressure of 2.5×10^{-2} mm Hg and a discharge current of 32 ma, the existence of a stable striated discharge with decaying striae is possible. We should add that in the same conditions a discharge without visible striae is also possible, but the increase of the cathode emission changes such a discharge into a striated one. The investigations were carried out within the regions of the first and second striae from the cathode by means of a movable cylindrical probe. Here the results of the investigations in the second stria are presented. The results for the first stria were similar. The length of each stria was of the order of 5 cm.

Fig. 2 shows oscillograms of second derivatives of the probe current with respect to the probe potential which, with an accuracy up to a factor proportional to *V*, represent the electron velocity distribution functions. The distance from the beginning of the stria to the point at which a given oscillogram was obtained is shown on each graph. Curves are plotted in different

scales. In order to have them in the same relative scale, the curves for 0. 0.5, 1.2, and 3.5 cm must be multiplied by 1, 2, 4, and 10, respectively.

The semilogarithmic characteristics plotted simultaneously, as well as the curve obtained from them for the space distribution of potential and the random electronic current density, were of a form similar to that obtained by Klyarfeld.[8]

It can be seen from the oscillogram that there is a group of fast electrons at the beginning of the stria. This group appears immediately after the potential rise at the beginning of the stria. As the distance from the beginning of the stria increases, the number of fast electrons decreases and the number of slow electrons becomes larger. Such an abrupt change in electron velocities can be accounted for by nonelastic collisions of electrons with atoms of the gas. This explanation is confirmed by the fact that some in the group of fast electrons have velocities of the order of 4.9 v, and also by the fact that the disappearance of this group takes place over the distance corresponding to several mean free paths from the beginning of the stria.

In conclusion we wish to express our appreciation to Professor S. E. Frish [Frisch], Corresponding Member of the USSR Academy of Science, for his interest in the present work.

---

[1]C. Haigh and T. Smith, Phil. Mag., **41**, 557 (1950).

[2]Kagan, Fedorov, Malyshev, and Gavallas, Doklady Akad. Nauk SSSR, **76**, 215 (1951).

[3]A. M. Bonch-Bruyevich, Doklady Akad. Nauk SSSR, **81**, 371 (1951).

[4]Yu. M. Kagan and V. M. Zakharova, *Trudy 8-vo Vsesoyuznovo soveshchania po spektroskopii* [Papers of the All-Union Conference on Spectroscopy], 1952.

[5]H. M. Druyvesteyn, Z. Physik, **64**, 781 (1930).

[6]A. H. Van Gorcum, Physica, **3**, 207 (1936).

[7]R. H. Sloane and E. I. MacGregor, Phil. Mag., **18**, 193 (1934).

[8]B. N. Klyarfeld, Zhur. ekspt1. i teort. fiz., **22**, 66 (1952).

Zhdanov State University of Leningrad
Received June 30, 1953; presented by Academician A. A. Lebedev June 30, 1953

AEC, Oak Ridge, Tenn.-W40963